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(54) Capability modeling using templates in network management system

(57) In a management system of a communications network comprising a plurality of network elements, capacity and capability of one or more individual network elements 800 is represented by a set of data templates. A first set of data templates 803-806represent internal construction and physical resources of a network element. A second set of templates 807-810 represent connectivity capabilities of the physical resources. The data templates are stored at an element controller, controlling a plurality of network elements. The element controller learns about the capacity and capabilities of the network elements, by receiving a set of reference messages generated by the network elements, over an operations, administration and maintenance channel. The reference messages point to the data templates stored at the element controller thereby enabling efficient enrollment of network elements by transmission of compressed messages over the operations, administration and maintenance channel.

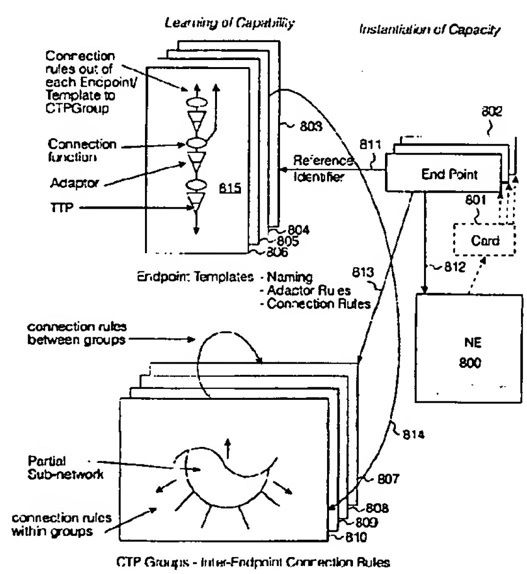

Fig. 8

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Description

Field of the Invention

[0001] The present invention relates to network management and particularly, although not exclusively to management of a communications network.

Background to the Invention

[0002] A conventional communications network, for example a broadband communications network comprises a plurality of physical resources, eg switches, cross connects, regenerators, repeaters, transmission links such as fiber optic links or coaxial cable links, operating under control of a plurality logical resources, eg transport protocols, and local controls associated with individual physical resources. An example of a generic representation of a communications network is illustrated in Fig. 1 herein, in which the physical resources are located at a plurality of nodes 100 and links 101 distributed over a geographical area. For a network operator to maintain control of a communications network for its operation, administration and maintenance, a management information base is maintained which stores information describing the physical and logical resources within the network. One or more management information bases may reside at a centralized location, eg a network controller 102, or different information bases may be situated at a plurality of network controllers at different locations. The management information base contains data describing each individual network element in a communications network. A conventional communications network may comprise of the order of hundreds of individual network elements, eg switches, cross connects, regenerators, each of which contains of the order of tens to hundreds of cards, having processors, line terminations, buffers, registers, switch fabrics, etc. each card containing of the order of hundreds of individual components. In general, a conventional communications network may comprise a multitude of different legacy equipment types of different proprietary manufacture, each of which has its own particular internal configuration and offers its own specific capabilities.

[0003] The International Telegraph and Telephone Consultative Committee (CCITT) of the International Telecommunications Union (ITU) in their recommendation G.774 published September 1992 (available from International Telecommunication Union, General Secretariat, Sales Service, Place de Nation, CH 1211, Geneva 20, Switzerland), specifies a recommended architecture of an information model for synchronous digital hierarchy (SDH) networks. In recommendation G.774, there is specified a model which describes managed object classes and their properties which are useful for describing information exchanged across interfaces defined in recommendation M.3010, telecommunications network management (TMN) architecture, also of the ITU-T. Recommendation G.774 identifies the telecommunications management network (TMN) object classes required for the management of SDH network elements, and specializes the generic object classes presented in recommendation M.3010 to provide management information specifically for synchronous digital hierarchy. These objects are relevant to information exchanged across standardized interfaces defined in recommendation M.3010 TMN architecture. In recommendation G.774, network resources are modeled as objects and a management view of a resource is referred to as a managed object. Objects with similar attributes may be grouped into object classes. An object is characterized by its object class and object instance, and may possess multiple attribute types and associated values. Object classes defined in recommendation G.774 apply to various management areas, for example fault management and configuration management. However, the inventors have experienced that the ways in which information is conveyed in accordance with methods specified in recommendation G.774 have several inadequacies.

[0004] Firstly, under conditions of equipment start-up, large amounts of data are transferred across the network, using up capacity on the operation administration and maintenance (OAM) channels. For example, for a network element having a shelf containing 25 line cards, on start-up each line card transmits enrol data describing each of the termination points on that line card, as well as data describing the relationships between the termination points on that line card. Every time the shelf is started up, the same termination point enrol data and relationship data is transmitted across the OAM channel to the management information base. For successive start-ups of the shelf, the enrol procedure is repeated, transmitting the same information on every start-up. Similarly, on starting up an identical shelf, the same enrol data is transmitted to the management information base, every time that other shelf is started up. Thus, under conditions of network fault, when a plurality of network elements are restarted, the whole enrol procedure for each network element is repeated. However, the information transmitted is basically static, ie the same as the information which was transmitted last time the shelf was started up.

[0005] Some prior art systems have addressed the problem of large data volumes on the OAM channel by operating on a principle of Assumed Management Knowledge. In these cases, a network manager assumes that certain network elements have certain capabilities and that they operate in a particular way. This avoids having to explicitly elicit the actual information concerning the operation of the elements from the elements themselves, or from another source in the network, since obtaining such information would cause a high level of management traffic. One consequence of

the assumed knowledge system is that assumptions may be erroneous and the network elements may operate in a way different to that assumed, leading to network management errors or less than optimal management of specific network elements, and of the network as a whole.

[0006] Secondly, the recommended management information model G.774, although providing for description of the content and configuration of a physical resource, does not adequately accommodate description of the capabilities of that physical resource. In particular, recommendation G.774 assumes potentially infinite flexibility of configuration of a described physical resource, whereas in practice there are practical limitations on the possible configurations of a resource. For example, physical resources may be subject to hard wired restrictions as a result of restrictions in an application specific integrated circuit (ASIC). Thus, irrespective of the way in which the physical resource is modeled in an information base, physical limitations on connectivity of the physical resource may exist. As an example, consider a physical resource having four ports numbered 1 to 4. Ports 1 and 2 may be capable of connecting with each other and to a further port, port 4. However, ports 1 and 2 may be incapable of connecting to port 3 due to a hard wired restriction on connectivity in the resource. However, recommendation G.774 does not provide a way of expressing such connectivity restriction, but assumes any port of the physical resource can be connected to any other port of the physical resource. Recommendation G.774 does not provide for description of such inherent capability restrictions in a physical resource.

Summary of the Invention

[0007] One object of the present invention is to provide an improved means for initialization of a management information base upon start up of physical resources in a network.

[0008] Specific methods according to the present invention may provide a means of increasing a flow of management information between a plurality of network elements and a management system, but using a lower amount of data transfer between the network elements and the management information base.

[0009] Another object of the present invention is to provide a means of conveying information concerning capabilities of physical resources to a management information system.

[0010] Specific methods according to the present invention may provide a means of describing capabilities of a physical resource which encompasses an unlimited range of possible capabilities, but which is also capable of describing specific limitations on capability within specific network element types.

[0011] According to one aspect of the present invention there is provided in a communications network comprising a plurality of network elements, a method of providing management data describing available capabilities of a said network element, said method charactierzed by comprising the steps of:

representing resources of said network element by at least one data template representation (803-806); and

referring to said data template representation by means of a message generated by said network element (800).

[0012] In a preferred implementation, said messages are communicated over an operations, administration and management channel of said communications network. The messages may provide an efficient means of compression of information transmitted over an OAM channel.

[0013] Preferably, said step of referring to said data template representation comprises the steps of:

representing each of a plurality of end points of said network element by a corresponding respective end point data (802), each said end point data comprising a reference to at least one said data template representation.

[0014] A said data template representation may comprise data describing a plurality of protocol layers operated by a said physical resource.

[0015] The physical resources suitably comprise a plurality of end points at which data packets, cells or frames may emerge or sink. The end points may comprise a physical or logical port. The physical resources suitably comprise a set of pre-configured structures, eg of layered termination points connected into end points.

[0016] Preferably, said step of representing resources by at least one data template representation comprises the step of representing connectivity capability between a plurality of ports of a said network element by a said data template representation.

[0017] Said step of representing resources of said network element by at least one data template representation may comprise the step of representing connections capability between a plurality of ports of said network element at a same layer as each other by a set of connection rules describing inter-port connections.

[0018] A set of said connection rules at a same layer may be collected into a connection group.

[0019] Said step of representing resources of said network element by at least one data template representation may comprise the step of representing connection capabilities between individual ports of a plurality of ports of said network element by a set of connection rules between said groups.

[0020] Suitably, each said port is represented by a corresponding respective end point data.
[0021] A said message may comprise a plurality of said end point data, each end point data representing a corresponding respective end point.
[0022] The invention includes a management system for managing a network element comprising a plurality of physical resources arranged into a plurality of pre-configured structures each of a pre-configured structure type, said management system comprising a data storage storing:

at least one data template, said data template representing a said pre-configured structure; and

a plurality of reference data, each said reference data referring to a said pre-configured structure and to at least one said data template.

[0023] According to a second aspect of the present invention there is provided a data representation of a physical resource operating in accordance with a protocol having a plurality of layers, said resource comprising at least one termination point in a said layer, at least one adaptation capability for adapting between said layer of said termination point and a client layer, and a connection capability for connecting said termination point, said data representation characterized by comprising:

termination point data (1302) describing a said termination point within a said layer;

adaptation rule data (1304) describing adaptation rules between said layer and a further layer; and

connection rule data (1306) describing connection capabilities of said termination point.

[0024] Preferably, said connection rules describe connection capabilities of said termination point within a same layer as said termination point.
[0025] Said connection rules may describe connection capabilities of said termination point to a layer other than a layer of said termination point.
[0026] Preferably, said termination point data comprises data describing a type of termination point.
[0027] Preferably, said adaptation rule data comprises data describing a relationship to a next rule in a logic list.
[0028] Characteristics of said termination point other than its layer may be stored in a sub-type of said termination point data component.
[0029] Said sub-type is preferably implemented as an ASCII field.
[0030] Said template may be implemented in UNIX external data representation (XDR) language. Said template may be implemented in common object related broker architecture interface definition language (CORBA IDL). Said template may be implemented in ASN1 GDMO, simple network management protocol (SNMP), JAVA, or C+ structure definitions.
[0031] Preferably, said adaptation data component comprises data describing a transport protocol. For example, said transport protocol may comprise synchronous digital hierarchy, or asynchronous transfer mode (ATM); or a 64 kilobits per second transport protocol. Said transport protocol may comprise synchronous optical network (SONET).
[0032] According to a third aspect of the present invention, there is provided in a communications network comprising a plurality of network elements, said network elements comprising a plurality of physical resources organized into a plurality of types of pre-configured structures, a method of providing management data describing available capabilities of said network elements, said method characterized by comprising the steps of:

representing a plurality of said physical resources by a set of data templates representations, and

representing said plurality of physical resources by a plurality of reference data, each said reference data referring to a said pre-configured structure and each said reference data referring to at least one said data template representation.

[0033] Suitably, each said data template represents a corresponding respective said pre-configured structure type.
[0034] A said pre-configured structure may comprise a layered structure, and a said data template may represent said layered structure.
[0035] A said pre-configured structure may comprise a layered structure having first and second layers, and a said data template may comprise: a termination point data describing at least one termination point at said first layer of said pre-configured structure; and a set of adaptation rule data describing adaptation rules for adapting between said first layer and said second layer of said pre-configured structure.
[0036] A said pre-configured structure may comprise a physical port, and a said data template may represent a

physical structure of said physical port.

[0037] A said pre-configured structure may comprise a logical port, and a said data template may represent a logical structure of said logical port.

[0038] A said reference data may refer to at least one said data template representation by means of a unique reference identifier.

[0039] A said data template representation may describe a set of connection capabilities between a plurality of individual said pre-configured structures.

[0040] Preferably, each said reference data refers uniquely to a single instance of a said pre-configured structure.

[0041] The invention includes a management system for managing a network element characterized by comprising a plurality of physical resources arranged into a plurality of pre-configured structures each of a pre-configured structure type, said management system comprising data storage means storing:

at least one data template, said data template representing a said pre-configured structure; and

a plurality of reference data, each said reference data referring to a said pre-configured structure and to at least one said data template.

[0042] Specific implementations of the present invention may enable an improved terminology for trail termination points.

[0043] In the one implementation according to the present invention, a connection function describing connections between a termination point in a self-layer and one or more termination points within a client layer.is provided by means of a set of connection rules, so as to enable description of configurable connections between a plurality of ports.

[0044] Further, specific implementations according to the present invention recognize that within a self layer, a trail termination point is always bound to a set of adaptation rules for adapting the self layer of a transport protocol to an adjacent layer of a transport protocol, and that an adaptation of data signals between layers of a transport protocol is always bound to a trail termination point.

[0045] By providing a set of rules describing adaptation of data between protocol layers, and by coupling the adaptation rules to a set of rules describing exit and entry to a layer, a concise description of an internal architectural configuration of a network element may be achieved. A plurality of such descriptions may be referenced to each other by means of a set of inter end point connection rules to provide a complete network element template describing functionality capabilities and internal physical constraints of the network element.

[0046] Further, specific implementations according to the present invention may provide for inter port connection rules of high complexity, which are configurable per network element.

Brief Description of the Drawings

[0047] For a better understanding of the invention and to show how the same may be carried into effect, there will now be described by way of example only, specific embodiments, methods and processes according to the present invention with reference to the accompanying drawings in which:

Fig. 2 illustrates a prior art representation of a synchronous digital hierarchy based transport layered model in accordance with International Telecommunications Union (ITU-T) recommendation G.803;

Fig. 3 illustrates schematically a prior art synchronous digital hierarchy multiplexer network element, illustrating connections to a plurality of tributary and aggregate layers;

Fig. 4 illustrates schematically a prior art synchronous digital hierarchy central office network element;

Fig. 5 illustrates schematically a prior art synchronous digital hierarchy layered multiplexing structure;

Fig. 6 illustrates an example of part of a communications network operating a network management system according to a first specific implementation of he present invention;

Fig. 7 illustrates schematically components and interconnection of a network element, element controller and network manager of the communications network of Fig. 6 herein;

Fig. 8 illustrates schematically a network element, having a plurality of cards, the cards represented by a set of data templates according to a specific implementation of the present invention;

Fig. 9 illustrates schematically a trail termination point data template representation according to the specific implementation of the present invention;

Fig. 10 illustrates schematically an example of a data template representation of ports of first and second network elements according to the specific implementation of the present invention;

Fig. 11 illustrates schematically an inter-relationship between first and second sets of connection rules according to the specific implementation of the present invention, each set of connection rules representing connectivity between ports of a network element;

Fig. 12 illustrates schematically a data template representation of a port of a network element according to the specific implementation of the present invention, illustrating representation of different protocol layers within the port;

Fig. 13 illustrates schematically a data template representation of a trail termination point at a physical media section layer of a SDH port as shown in Fig. 12;

Fig. 14 illustrates a data template representation of a trail termination point at an optical section layer of the SDH port as shown in Fig. 12;

Fig. 15 illustrates a data template representation of a trail termination point at a regenerator section layer of the SDH port as shown in Fig. 12;

Fig. 16 illustrates schematically a data template representation of a trail termination point at a multiplexed section layer of the SDH port as shown in Fig. 12;

Fig. 17 illustrates schematically a data template representation of a trail termination point at a higher path layer of the SDH port as shown in Fig. 12;

Fig. 18 illustrates schematically a set of adaptation rules of the data template representation of Fig. 17;

Fig. 19 illustrates schematically messaging between an element controller and the network manager for obtaining a list of network elements;

Fig. 20 illustrates schematically messaging between an element controller and a network manager for obtaining from the element controller a list of end points describing ports;

Fig. 21 illustrates schematically messaging between a network manager and an element controller for obtaining from the element controller a set of end point data templates representing internal physical resources of a plurality of ports of a network element;

Fig. 22 illustrates schematically messaging between a network manager and element controller for obtaining from the element controller a set of connection termination point group data templates describing inter-connectivities between ports of a network element; and

Fig. 23 illustrates schematically messaging between an element controller and a network manager for enroling a plurality of ports at the network manager.

Detailed Description of the Best Mode for Carrying Out the Invention

[0048] There will now be described by way of example the best mode contemplated by the inventors for carrying out the invention. In the following description numerous specific details are set forth in order to provide a thorough understanding of the present invention. It will be apparent however, to one skilled in the art, that the present invention may be practiced without using these specific details. In other instances, well known methods and structures have not been described in detail so as not to unnecessarily obscure the present invention.

[0049] In the following discussion, a best mode implementation of the invention is described with reference to synchronous digital hierarchy (SDH) systems. However, it will be understood that the scope of the invention is not restricted to SDH systems, but extends over any network of physical and logical resources in the telecommunications or computer

networks domains, having a management information system. Networks operating asynchronous transfer mode (ATM), synchronous optical network (SONET), integrated service digital network (ISDN) and SDH are specific examples of such networks. However, the invention is not restricted to networks operating these specific protocols.

[0050] Within the following description, references are made to terms defined in International Telecommunications Union (ITU-T) recommendations G.803 and G.805. In this specification, definitions of terms according to recommendation G.805 are to take precedence over definitions of the same terms appearing in recommendation G.803.

[0051] ITU-T recommendation G.803 deals with the architecture of SDH transport networks and defines an SDH based transport network layered model as illustrated in Fig. 2 herein. The G.803 model uses a functional approach to the description of architectures based on the concept of a number of SDH functional layers, and the concept of partitioning within a layer for defining administrative domains and boundaries. Physically, a conventional SDH network is constructed from a plurality of physical resources, for example network elements such as exchanges, multiplexers, regenerators, and cross connects. The network elements are connected together and provide a transmission media layer, including a section layer comprising a multiplex section layer 200, and a regenerator section layer 201, and a physical media layer 202. Circuit switched traffic is routed over the physical resources in a circuit layer 203 which is carried by the SDH transport layers.

[0052] Examples of prior art SDH network elements are illustrated schematically in Figs. 3 and 4 herein. Referring to Fig. 3 herein, there is illustrated schematically a synchronous digital multiplexer element 300, forming a basic component of a known synchronous digital hierarchy network. By providing a multiplexer with a range of optional tributary interfaces 301, a single synchronous multiplexer can provide a wide range of access bitrates for a variety of needs, for example 1.5 Mbit/s, 2 Mbits/s, 6 Mbits/s, etc, such low bitrate access being multiplexed into a plurality of higher synchronous transfer mode aggregate rates 302, for example STM-4, STM-16 or STM-64. Prior art synchronous digital hierarchy networks may be assembled from a plurality of such multiplexer elements in a variety of different configurations, including add-drop, ring or hub configurations.

[0053] Tributary interfaces provide access to higher order transmission rates for exchanges. Exchanges are connected to each other using optical connections operating high bitrate synchronous modes. Subscribers access the SDH network using an access network which enters the exchanges and multiplexers using, for example 2 Mbits/s tributaries. An example of a known SDH exchange is illustrated schematically in Fig. 4 herein.

[0054] Data is carried between network elements which are geographically separated by large distances at relatively high data rates, eg 155 Mbits/s. Circuit switched connections, referred to as a circuit layer 203 in recommendation G. 803 are transported across the SDH network by encapsulating bit streams comprising the circuit switched connections into different virtual containers (VCs) which are multiplexed together for transmission at higher order bit rates. The SDH transport layers comprise, in addition to the physical media layer and section layer, a plurality of higher order path layers, for example carried by virtual containers VC-3, VC-4, and a plurality of lower order path layers, for example carried by virtual containers VC-2, VC-3, VC-11, VC-12.

[0055] The SDH layered multiplexing structure is illustrated schematically in Fig. 5 herein, illustrating also synchronous optical network (SONET) multiplexing options, and European Telecommunications Standards Institute (ETSI) multiplexing options.

[0056] Within the physical resources, circuit switched traffic follows paths and trails at various multiplex levels. Connections are terminated at connection termination points, and trails are terminated at trail termination points within physical resources. For example, within a communications network, there may be a restricted number of network elements which are capable of processing voice data. Operations on voice data at a voice level may be performed within those particular network elements. However, to transport traffic data between those network elements, there must be further transmission, such as provided by the SDH virtual container system. Thus, where a voice connection is to be made between geographically disparate network elements A and B, the connection may be routed via intermediate network elements D, E, F, G etc which may be in the VC-12 layer. However, the VC-12 layer itself, to connect between intermediate network elements E, F may need to be mulitplexed into a higher bitrate layer, eg the VC-4 layer.

[0057] Referring to Fig. 6 herein, there is illustrated schematically a section of an SDH communications network comprising a plurality of network elements 600 - 605 operating under control of an element controller 606 and managed by a network manager 607 according to a specific implementation of the present invention. The element controller communicates with the plurality of network elements via a prior art network management protocol, for example the known common management information service element (CMISE) protocol 608 or the known Hewlett Packard Simple Network Management Protocol (SNMP), and the element controller communicates with the network manager 607 via a prior art protocol for example the known UNIX compatible external data representation (XDR), carried by the known transmission control protocol/internet protocol (TCP/IP) over transmission link 609. In the specific implementations described herein, templates and messages are transported using the known external data representation. However, the invention is not restricted to use of the known external data representation for this purpose, but may alternatively be implemented by a common object related broker architecture interface definition language (CORBA IDL), in ASN1 - GDMO, in SNMP, JAVA, or C+ structure definitions. For clarity of explanation, the XDR implementation will be referred

to in the best mode hereafter. The network manager 607 implements operations, administration and management of the network elements, through element controller 606.

[0058] Referring to Fig. 7 herein, there is illustrated schematically construction of a typical network element 700, element controller 606 and network manager 607. Network element 700, for example a multiplexer or cross connect, comprises a casing or cabinet having one or a plurality of shelves, each shelf containing a plurality of cards 701. The physical resources of the network element are carried on the cards 701. The cards contain processors, switch fabrics, line terminations etc depending upon the type of network element, and are connected to each other via a data bus. The physical resources are arranged into a set of pre-configured physical and logical structures. For example. A physical resource may comprise a physical port as will be described hereafter. A logical structure may comprise a logical port floating between cards, as will be described hereafter. A pre-configured structure may comprise a logical structure of connection capabilities between individual ports, as will be described hereafter. In the case of an SDH multiplexer, each card may support a number of physical ports. Each port supports a plurality of connections.

[0059] The network element is provided with a local control system 702 comprising a data processing capability configured to send and receive messages over the CMISE operations administration and maintenance channel 608 and providing control of network element functionality.

[0060] The element controller comprises a workstation 703, for example a Hewlett Packard 9000 series workstation comprising a processor 704, a data storage device 705, a bus 706 linking the processor and data storage device, a graphical user interface 707, and a communications port 708 for communicating with the network element and the network manager. Typically, the element controller operates according to a UNIX operating system 709.

[0061] The network manager 607 similarly may comprise a work station 710, eg Hewlett Packard 9000 series having processor 711, memory 712, bus 713, graphical user interface 714 and communications ports 715, operating in accordance with a UNIX operating system 716. The network manager and the element controller are configured to communicate with each other using for example TCP/IP link 608. The network manager comprises a managed object base (MOB) 717 containing data describing characteristics and configurations of the network elements under its management. Within the network manager, each network element is represented as a managed object, in accordance with the known telecommunications network management network (TMN) architecture of ITU-T recommendation M.3010. The managed object base comprises a database from which a plurality of network management applications resident on the network manager may source data describing the network, in order to perform network management operations, eg fault management, provisioning, and configuration operations.

[0062] According to the best mode implementation of the present invention described herein, there are provided a set of data templates representing the physical resources provided by the network elements. The templates 718 as will be described hereafter in this document, describe the capabilities and internal connectivities of one or a plurality of pre-configured structures, eg ports within the network elements. In general, network elements comprise a limited set of physical arrangements of hardware components, that is to say a limited set of pre-configured physical structure types are present in a network element or a family of network elements and can be represented by a limited set of data template types. Similarly, logical connectivities between physical pre-configured structures tend to repeat across a family of network elements, and can be represented by a limited set of data template types. Each different type of network element having its own particular capability and connectivity may be represented by a different set of template types.

[0063] In the specific implementation of the best mode herein, the element controller stores a plurality of templates describing the network elements and sends these to the network manager over communications link 608. Templates may be stored in the managed object base 717 in addition to the managed objects 719 configured according to the known TMN architecture. Optionally, each network element may store one or more templates describing its ports. Installation of templates describing a network element into the network element is left as an option for a manufacturer of the network element. The templates may be read by one or more applications resident on the network manager. One such application comprises a trail manager application 720 for managing creation, deletion and modification of trails across the network. The trail manager application is the subject of a separate patent application filed on the same day, and at the same government patent office as the present disclosure.

[0064] Within the element controller 606, a managed object agent (MOA) 721 implements management of the network elements according to instructions received from the network manager 607. The managed object 721 uses data of the templates to manage the network elements.

[0065] Referring to Fig. 8, herein there is illustrated a system for describing and communicating internal configuration and capabilities of a network element 800 using a set of data templates and messages. Network element 800 comprises a plurality of cards 801, each card having a plurality of physical and/or logical ports. A "port" is defined in recommendation G.805 as "a pair of uni-directional ports". A uni-directional port as defined in recommendation G.803 "represents the output of a trail termination source of a uni-directional link connection, or the input to a trail termination sink or uni-directional link connection". Logical ports exist within a network element and may have similar layer structures and characteristics as physical ports, but do not actually bind to any physical port externally to the network element. Logical

ports may be bound to one card, or may float across a plurality of cards. The physical or logical ports of a card may all be of a same type, or several different types of port may be resident on a card, depending on the specific manufacture of the network element itself.

[0066] Each physical or logical port is represented in the specific implementation herein as a corresponding respective end point. In this specification, the term "end point" is used to describe a port comprising a receive port, and (optionally) a transmit port. Each port of the network element is described by reference to its own end point data 802 which is unique to the end point and is enrolled at the element controller by means of an end point message. The end point message comprises one or a plurality of end point data. The end point data comprises a reference data, which refers uniquely to one end point, and which refers to one or more data templates. A card has a plurality of end points, depending on how many physical and logical ports it has.

[0067] The templates are of two types: Firstly, a set of end point templates 803 - 806 describe individual port types. Secondly, a set of connection termination point (CTP) group templates 807 - 810 describe inter-connectivities between ports.

[0068] An end point data 802 of a port comprises a reference identifier 811 to an end point template, a reference identifier 812 to a port, and may comprise a reference identifier 813 to a CTP group template. An end point template, eg 805, may include a reference identifier 814 to a CTP group template.

[0069] Each end point template contains the following:

- A layer tree 815 including all of the types of trail termination point with the number of instances of the end points associated with the end point template.
- An instantiation naming relationship between trail termination points in the tree.
- Adaptor rules for each trail termination point type in the tree.
- Connection rules for each trail termination point type or derived connection termination point type in the tree.

[0070] A single end point template may represent a plurality of individual instances of end points. An end point template describes for a port a hierarchy of termination points and limited connection functionality within those termination points, which arrive at the element controller at the same time, and which are bound to a same set of hardware as the port, or which are activated by the arrival of an end point data for that port and which are bound into a same set of hardware.

[0071] Connectivity between individual end points is represented by the set of CTP group templates. CTP group templates contain inter-end point connection rules which supply the compatability and connectability rules for operation across a trail at each layer of the model. Relationships between ports within a network element are conveyed by CTP group templates. Different types of connection, eg uni-directional, bi-directional, which can be made between ports is described by the CTP group templates. The CTP group templates model physical limitations on inter-port connections, eg due to lack of buses, physical tracks, limited capacity, etc. Information contained in a CTP group template may be used by higher applications in the management system to determine whether a connection can be made or not.

[0072] The end point templates and CTP group templates are constructed from assembling a plurality of smaller templates each representing a trail termination point in a layer. Such data templates are referred to herein as "trail termination point templates" and contain data describing a trail termination point, adaptation nodes concerning adaptation of that trail termination point, a client layer, and rules describing connectivity of that trail termination point to other trail termination points within its layer (intra-layer rules), and also connection rules describing connectivity of that trail termination point to other layers (inter-layer rules).

[0073] Construction and content of the end point data, end point messages and data templates will now be described:

End Point Data

[0074] An end point data represents an instance of a port. Each end point data comprises a reference identifier to a corresponding end point template. A set of end point data of a card provides a set of reference identifiers to one or more end point templates. Each end point template describes a type of physical or logical port of the card.

[0075] An end point data comprises the following:

- a list of locations of connection termination points of a port. A first location (primary location) relates to a receive port, and a second location (if present) relates to a transmit port. If any special supporting hardware is present in the port, the location of this hardware may be referenced by a third location. In the best mode herein, one location is listed, this being the primary location which is used to refer to the end point.

- a reference identifier to an end point template
- (optionally) a reference identifier to a connection termination point group template
- a text string name of the end point as used on the element controller or at the network element. For example the G scheme number for the TN-16X, or the shelf/slot number of the TN-4X such as "301" naming scheme.
- a text string user label for the end point.

End Point Messages

[0076] An end point message of a port contains the end point data of that port. End point messages are transmitted from the network elements to the element controller 606 over the operations administration and management channel 609. The end point messages comprise the end point data (one per each port instance) carried within a protocol used for the operations administration and maintenance channel, eg the prior art CMISE protocol. The end point messages are relatively short, and occupy relatively little data carrying capacity on the OAM channel. By transmission of end point messages over the OAM channel to enrol ports of a network element, by reference to existing end point templates stored at the element controller, significant reductions in enrol times for ports of network elements may be achievable compared with prior art management systems.

End Point Templates

[0077] Each end point template is written specific to a particular port type. A plurality of individual ports of a same type share a same end point template.

[0078] Within an end point template, a port is described in terms of its layer structure, eg SDH layers, and in terms of a plurality of termination points and adaptations, and the constraints on connectivity between layers within that port. Each end point template describes connectivity constraints between layers within a set of termination points which bind directly to a particular logical or physical port which the end point template describes. Connectivity between layers is described herein as vertical connectivity. Connectivity between different ports at a same layer is referred to herein as horizontal connectivity. A set of end point templates describes the capacity of a network element and any limitations on the capabilities of the network element.

[0079] An end point template may be implemented as a list of parameters, which are read by a parser in the network manager, and in the element controller. In the best mode herein, an end point template comprises a list of parameters identifying the end point template and a list of parameters describing a content of an end point.

[0080] An end point template comprises the following elements:

- A plurality of trail termination point templates within the port. An end point template is constructed from one or a plurality of trail termination point templates as described with reference to Fig. 9 herein.
- An end point template identifier parameter. The end point identifier uniquely identifies an individual end point template. Each end point template identifier comprises an end point template number, an end point template name and an endpoint template parser vintage parameter. The end point template number is unique to a specific end point template and describes details of the template, for example the type and version of the template. In a large network comprising a large number of different network elements, a large number of different port types may exist, each one having a unique end point template. Further, as ports are upgraded, existing templates may need to be upgraded. The end point template number and end point template name are specific to a particular template type and do not change once allocated to that end point template type. If a change to a template is necessary, then a new end point template having a new end point template identifier is produced. As end point templates are modified, the network manager and element controller may operate different parser versions to each other. The vintage parameter enables identification of the appropriate vintage of parser for use with the end point template.
- A parameter identifying a directionality of the connection termination point. For example the parameter may specify whether direction is or is not applicable, whether the connection is bi-directional or uni-directional, whether a transmit port is uni-directional and whether a receive port is uni-directional.
- a reference identifier to a list of CTP group templates associated with the end point.
- a number of instances of connection termination points within the port.

[0081] A parameter describing a trail termination point template (*struct xdr_ tmcom_ttp_template*) comprises a parameter describing details of a trail termination point; directionality of the trail termination point; a number of instances of the trail termination point; connection rules concerning connections to other trail termination points in a same layer; a list of adaptation rules for adapting between layers: a list of assembly rules and a list of connection rules for connecting the trail termination point to a client layer.

[0082] An example of a data structure describing a trail termination point template may be as follows:

```
struct xdr_tmcom_tp_details (
  xdr_tmcom_tp_type                tp_type;
  xdr_tmcom_tp_type_qualifier          tp_qualifier;
  xdr_tmcom_tp_sub_type                tp_sub_type_list<>;
  );
struct xdr_tmcom_ttp_template (
  xdr_tmcom_tp_details
                          ttp_details;
  xdr_tmcom_directionality
```

Trail Termination Point (TTP) Template

[0083] Referring to Fig. 9 herein there is illustrated terminology for describing a trail termination point at a layer of a synchronous digital hierarchy network. An end to end trail may be described by assembling a plurality of such trail termination points. Although the example of Fig. 9 herein is described specifically with respect to a SDH environment, the naming scheme illustrated by Fig. 9 is applicable more generally to ports operating other protocols having terminations and layers. For example the North American Synchronous Optical Network (SONET) protocol, or the asynchronous transfer mode (ATM) protocol in which there are adaptation layers, virtual circuits and virtual paths.

[0084] In a naming scheme according to a specific method of the present invention, internal capabilities of physical resources of a communications network are described by way of a trail termination point template 900. A naming scheme for such a template is as follows:

[0085] Triangle symbol 901 represents a trail termination point, either bi-directional or uni-directional.

[0086] Quadrilateral symbol 902 represents an adaptation layer, either bi-directional or uni-directional.

[0087] Symbol 903, an irreducible composite of symbols 901 and 902, represents that an adaptation is always associated with a termination point.

[0088] Inverted semi-ellipse symbol 904 represents an entry connection function from a client layer into an adaptation represented by symbol 901.

[0089] Semi-ellipse symbol 905 represents an exit connection function from trail termination point 902.

[0090] The trail termination point template illustrated in Fig. 9 herein comprises an irreducable segment for describing a trail termination point within a port. The assembly of entry connection function 904, adaptation layer 901, trail termination point 902 and exit connection function 905 in the specific implementation herein recognizes a strict binding of functions represented by those symbols in a transport entity. In practice, these elements are always associated with each other and are never separate.

[0091] A plurality of trail termination point templates 900 as illustrated in Fig. 9 may be assembled together to provide a comprehensive definition of internal structure and capability of a network element. A plurality of trail termination point templates are assembled into an end point template as described previously herein for describing a port type. The end point templates are reusable, and may be referenced by a plurality of ports of a same type within a network element. Elements represented by symbols 901 - 905 in Fig. 9 are further detailed as follows: In the following, description of the elements 901 - 905 is made with reference to the XDR language in which the templates are carried in the specific implementation herein.

[0092] A trail comprises any circuit, line, path or section into which, at a first end, is inserted a data stream, and at

a second end, is output the data stream. Within the trail, a data stream may be packaged into one or a plurality of frames or protocols, eg an STM frame, an ATM frame or a SONET frame. According to ITU-T recommendation G.803 a trail is defined as a "transport entity" in a server layer responsible for the integrity of transfer of "characteristic information" from one or more client network layers between server layer "access points". It defines the association between "access points" in the same "transport network layer". It is formed by combining a near end "trail termination" function, a "network connection" and a far end "trail termination" function. A trail termination point comprises an end point of a trail. According to ITU-T recommendation G.803 a trail termination is defined as a "transport processing function" which generates the "characteristic information" of a layer network and ensures integrity of that "characteristic information". The "trail termination" defines the association between the "access point" and "termination connection point" and these points therefore delimit the "trail termination". According to ITU-T recommendation G.805 a "trail" is defined as "a "transport entity" which consists of an associated pair of uni-directional trails" capable of simultaneously transferring information". A uni-directional trail is defined as "a "transport entity" responsible for the transfer of information from the input of a trail termination source to the output of a trail termination sink. The integrity of the information transfer is monitored. It is formed by combining trail termination functions and a network function. According to ITU-T recommendation G.805, a trail termination is defined as "a "transport processing function" that consists of a co-located trail termination source and synch pair". For example, a VC-12 trail comprises a route over which a VC-12 container envelope passes from source to destination, for example on entry to the VC-12 trail, the incoming data stream is packaged into a VC-12 envelope, and at the destination of the VC-12 trail, the data is recovered from the VC-12 container. A trail may traverse a plurality of physical or logical resources.

[0093] A trail termination point 901 is represented as an object. Attributes of such an object comprise:

- termination point type (*tp_type*) - this attribute defines the type of trail termination point, for example a physical media section termination point, a regenerator section termination point, an optical section termination point, a multiplex section termination point, or a higher order path termination point, layer;
- a termination point qualifier (*tp_qualifier*) - data which qualifies the "type" data. For example where the type of termination point is a physical media section termination point, this may be qualified by further specifying that the transmission medium is fiber. In other cases, there may be no qualifiers, in which case a null value is entered as a *tp_qualifier* attribute. In other cases, for example where the type is a higher path (*HP*) the qualifier may specify a VC4 layer;
- a termination point sub-type list (*tp_sub_type<O>*) - an attribute comprising an ASCII text field describing further subsidiary details about the type of termination point. This attribute is optionally filled, and a null value may be entered.

[0094] Adaptation element 902 comprises a set of adaptation rules describing adaptation between a self layer of a trail termination point and a client layer of the trail termination point.

[0095] Adaptation as represented by quadrilateral symbol 902 is defined generically in ITU-T recommendation G. 805 as "a "transport processing function" that consists of a co-located adaptation source and synch pair". Adaptation is defined in recommendation G.803 as "a "transport processing function" which adapts a server layer to the needs of a client layer. The "adaptation" function defines the server/client association between the "connection point" and "access point" and these points therefore delimit the "adaptation" function. "Adaptation" functions have been defined for many "client/server" interactions".

Adaptation Rules

[0096] The layer tree in each end point template specifies the types of trail termination point associated with a specific end point. Each layer of the tree adapts to the other layers by means of a set of adaptation rules.

[0097] In the specific implementation herein, an example of a set of adaptation rules is represented by a set of parameters as follows:

```
struct xdr_tmcom_adaptation_rules (
  xdr_tmcom_mapping_group_id                 mapping_group_id<>;
  xdr_tmcom_adaptation_rules_logic_list      adaptation_logic_list<>;
);
```

Parameter	Legal Range
ctp_group<>	0 for no parameter of default 1 or more ctp groups where rule requires this parameter
type_of_connections_allowed	0 for no connection type or default 1 or more connection type where rule requires this parameter
specific_cp_name<>	0 for no ctp or default 1 or more ctp where rule requires this parameter
list_of_valid_points<>	0 where rule does not require points 1 or more where rule requires this parameter
specific_ttp_type<>	0 for no ttp of default 1 or more ttp where rule requires this parameter
allowed_directionality	where it differs from the TTP
broadcast_limit	1 where no broadcast

```
struct xdr_tmcom_adaptation_rules_logic_list (
  unsigned long                    instances_of_mapping_component;
  unsigned long                    capacity<>;
  xdr_tmcom_mapping_group_id       mapping_component_structure;
  xdr_tmcom_tp_details             mapping-component_tp;
  xdr_tmcom_adapter_rule_operator
                                   relationship_to_next_rule)in_logic_list;
);
```

instances_of_mapping_component	number of instances of the mapping component currently being defined.
mapping_component_structure	describes the id of the mapping group which this layer adapts to.
capacity	This value should be set to NULL (empty list) for SDH.
mapping_component_tp	tp_details for this mapping component.
Relationship_to_next_rule_in_logic-list	logic operator describing the relationship between the current adaptor rule in this layer and the next (if any) adaptor rules in this layer.
Note: if it maps to a ttp then the mapping component will be null and vice versa.	

```
Enum xdr_tmcom_mapping_group_id (
  xdr_tmcom_null_mapping_group_id,
  xdr_tmcom_HP_VC4_TUGmap,
  xdr_tmcom_HP_VC3_TUGmap,
  xdr_tmcom_MS_AUGmap,
  xdr_tmcom_TUG2,
  xdr_tmcom_TUG3,
  xdr_tmcom_ATM_VPmap,
  xdr_tmcom_AUG
);
```

Value	Description
0	Null mapping group
1	HP_VC4_TUGmap
2	HP_VC3_TUGmap
3	MS_AUGmap
4	TUG2
5	TUG3
6	ATM-VPmap

```
enum xdr_tmcom_adapter_rule_operator (
  xdr_tmcom_null_adapter_rule_operator
  xdr_tmcom_OR
  xdr_tmcom_AND
;
```

[0098] A set of end points referencing to a network element describe all the physical and logical ports available within that network element, ie the physical and logical resource capacity available in that network element, and for each end point, an end point template describes the vertical connectivity constraints of termination points of the corresponding port. End point templates describe intraport connectivity and model inherent connectivity constraints within a port, eg as limited by hardware. Horizontal connectivity capabilities between different ports, at various different protocol levels is described by a set of inter end point connection rules specific to the network element. Such connection rules are referred to herein as CTP group templates.

CTP Group Templates

[0099] CTP group templates describe how end point templates are interconnected in terms of a set of connection rules. A set of end point templates, end point data and CTP group templates corresponding to a network element interrelate with each other to give a detailed description of resources available within a network element, and the capabilities which they provide. The end point data, end point templates and CTP group templates describe all ports, including

trail termination points at all layers within the ports. A single network element has one or a plurality of CTP groups. Each individual CTP group is represented as an instance of a CTP group template. A CTP group template comprises the following elements:

- A CTP group identifier which is unique to a specific CTP group template and describes the type and version of the CTP group template. The identifier comprises a *group_number* parameter and a *group_name* parameter. The *group_number* and *group_name* parameters are unique to a particular CTP group template and are not changed once allocated to that template. If a new CTP group template is created, then a new template identifier is allocated to that template. The *group_name* parameter provides a meaningful description of the template, for example "*TN4x-STM4-all_endpoints_vers_1_1*". Additionally, the template identifier comprises a vintage parameter (*ctp_group_parser_vintage*) which identifies the version of parser for which the CTP group template was written.

[0100] The inter end point connection rules describe:

- connections between termination points of different ports at a same layer. Each connection termination point group comprises connection rules specifying connectivity of termination points at a same layer between different ports; and
- connections between groups of termination points at one layer and groups of termination points at other layers. Connections between termination points at one layer and termination points at other layers are described as a set of connection rules between groups of termination points.

[0101] Connection rules are used at the connection termination points to describe which layer(s) a current layer may connect to. The connection rule express relationships between adapted trail termination points, and other trail termination points of a compatible layer, both inside the end point template and outside the end point template as appropriate.

[0102] An example of a set of connection rules used in the specific implementation herein, various ones of which may be used internally within end point templates, and various ones of which may be used in CTP groups, externally of end point templates is as follows:

Parameter	Comments
connection_rule	Rule for connectivity
rule_parameter_list	0 for entries with no parameters, 1 for entries with parameters

enum xdr_tmcom_connection_rule_name (

xdr_tmcom_must_not_connect_to_ctp_in_group,

xdr_tmcom_may_connect_to_any_ctp_in_group,

xdr_tmcom_may_connect_to_any_ctp_on_one_to_one_basis_in_group,

xdr_tmcom_use_ctp_group_rules,

xdr_tmcom_must_connect_to,

xdr_tmcom_must_not_connect_to,

xdr_tmcom_may_connect_to,

xdr_tmcom_must_be_connected,

xdr_tmcom_may_connect_to_self,

xdr_tmcom_broadcast_limit,

xdr_tmcom_connects_externally,

xdr_tmcom_reversion_supported,

xdr_tmcom_reversion_always_enabled,

xdr_tmcom_protection_switch_state_not_controllable,

xdr_tmcom_protection_switch_always_auto,

xdr_tmcom_protection_switch_always_manual,

xdr_tmcom_supports_only_subnetwork_protection,

xdr_tmcom_supports_only_path_protection,

xdr_tmcom_supports_path_and_subnetwork_protection,

);

connection rule name	parameter(s) from xdr_tmcom_rule_parameter	comments
xdr_tmcom_must_not_connect _to_ctp_in_group	one or more ctp_group	If no group name then it assumes all groups that the end point belongs to
xdr_tmcom_may_connect_to_any_ctp_in_group	one or more ctp_group one or more specific_ctp_name AND/OR list_of_valid_points AND/OR type_of_connection s_allowed	If no group name then it assumes all groups that the end point belongs to
xdr_tmcom_may_connect_to_ any_ctp_on_one_to_one_basis any_ctp_on_one_to_one_basis _in_group,	one or more ctp_group one or more specific_ctp_name AND/OR one or more specific_ttp_type AND/OR list_of_valid_points AND/OR type_of_connection s_allowed	If no group name then it assumes all groups that the end point belongs to
*xdr_tmcom_use_ctp_group_*	-	Used in end point templates. Assumes that
rules		all ctp groups identified in the end point (template) should be used. If this rule is not states then the ctp group rules d not apply and connectivity is only possible in the end point.

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(54) **Capability modeling using templates in network management system**

(57) In a management system of a communications network comprising a plurality of network elements, capacity and capability of one or more individual network elements 800 is represented by a set of data templates. A first set of data templates 803-806represent internal construction and physical resources of a network element. A second set of templates 807-810 represent connectivity capabilities of the physical resources. The data templates are stored at an element controller, controlling a plurality of network elements. The element controller learns about the capacity and capabilities of the network elements, by receiving a set of reference messages generated by the network elements, over an operations, administration and maintenance channel. The reference messages point to the data templates stored at the element controller thereby enabling efficient enrollment of network elements by transmission of compressed messages over the operations, administration and maintenance channel.

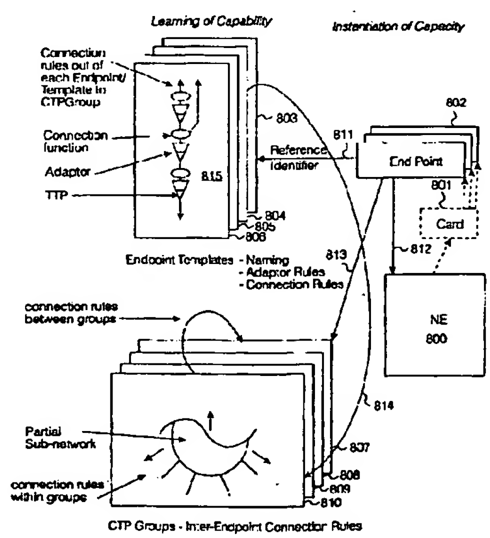

Fig. 8

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EUROPEAN SEARCH REPORT

Application Number
EP 98 30 6103

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	SESHAKE H ET AL: "DATA COMMUNICATION PLATFORM IN DISTRIBUTED OPERATIONS SYSTEM BASED ON TMN" IEEE NETWORK OPERATIONS AND MANAGEMENT SYMPOSIUM (NOMS),US,NEW YORK, IEEE, vol. SYMP. 5, 1996, pages 349-359, XP000634802 ISBN: 0-7803-2519-2 paragraphs "Composing Invoke ID"; "Message Delivery";	1,11,29, 38	H04Q11/04 H04L12/24 H04Q3/00
A	MAKOTO YOSHIDA: "AN OVERVIEW OF NEXT-GENERATION OPERATIONS SYSTEMS. TOWARD OPERATIONS AND MANAGEMENT WITH CUSTOMER PARTICIPATION" NTT REVIEW,JP,TELECOMMUNICATIONS ASSOCIATION, TOKYO, vol. 6, no. 3, 1 May 1994 (1994-05-01), pages 59-65, XP000467000 * paragraph '0001! *	2	
A	EP 0 585 082 A (COMPAQ COMPUTER CORP) 2 March 1994 (1994-03-02) * abstract *	1,11,29, 38	TECHNICAL FIELDS SEARCHED (Int.Cl.6) H04Q H04L
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	16 February 2000	Staessen, B

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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